Musical Humanoids

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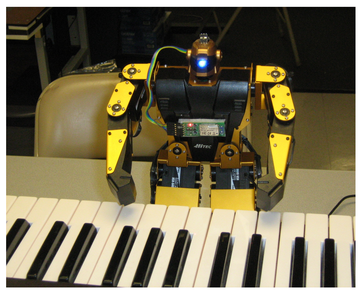
Abstract

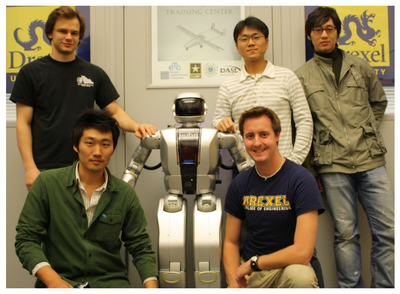
Humanoids have become increasingly capable in recent years. Enabling these robots to mimic human musical activities is an ongoing area of research; however, most developments in this field have employed pre-programmed motions, and robots remain incapable of responding to changes in music. We have developed algorithms that allow a small humanoid robot, RoboNova, to dance to music and play notes on a keyboard. This robot serves to prototype our algorithms before applying them to Hubo, a more advanced life-sized humanoid. We hope to make Hubo capable of musical interaction, thereby providing a platform to study robot motor control and human creative expression.

RoboNova and Hubo

The RoboNova is a 14" humanoid robot developed by HiTec Robotics. It has 16 degrees of freedom, is easily repaired, and has a simple developing environment. This allows us to rapidly prototype and improve our algorithms.

Hubo is a 4' humanoid robot produced by the Korea Advanced Institute of Science and Technology. It has 41 degrees of freedom and can produce smooth, human-like motions [1]. This makes Hubo a good platform for our final algorithms.





Musical Robots

Musical activities, such as dance motions and piano playing, require a great deal of precision and technique. The motor skills developed for these activities could potentially be applied to other topics. Humanoids can perform motions an unlimited number of times, identically or with minute variations. They are, therefore, ideal platforms for studying expressive gestures. Synthesizing human-like gestures using quantifiable parameters allows us to analyze these motions with greater precision than is possible with human-performed gestures.

Control

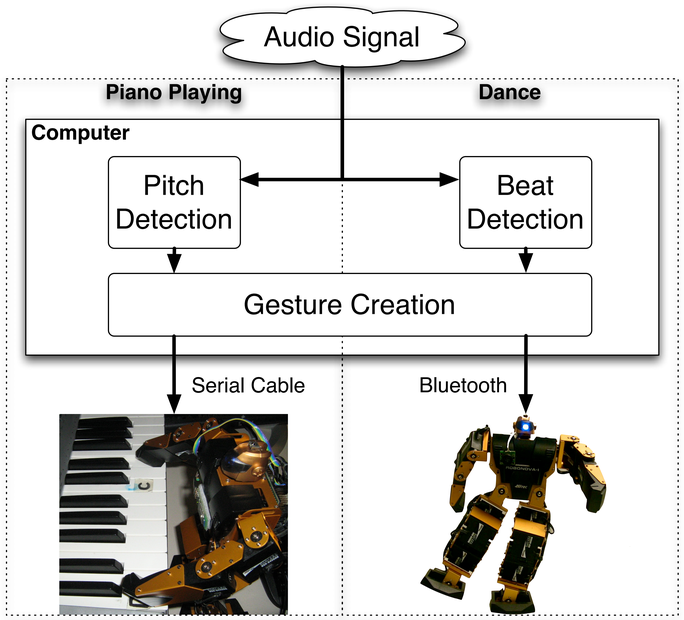
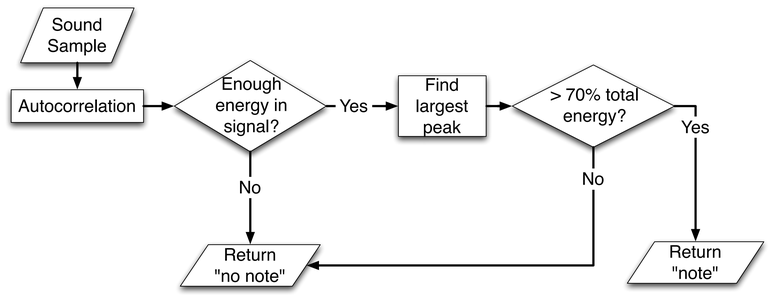


Figure 1: System for controlling the robot platforms.

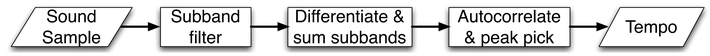
Pitch Detection

In order to detect notes, ambient sound is sampled in 0.1 second frames. Our algorithm uses autocorrelation to detect pitch in the sample, where the fundamental frequency of the sound corresponds to the highest peak in the autocorrelation.

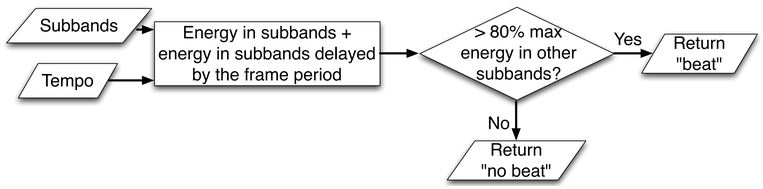


In order to differentiate notes from ambient noise, the sound sample must meet two criteria. The first is that there must be a minimum amount of energy in the signal (ie. the sound must be loud enough). If the sound is too quiet, it is assumed to be background noise and is disregarded. The second criteria is that this fundamental must contain at least 70% of the total energy in the signal. This rules out noises that are loud but not periodic.

Beat Detection



The application calculates the tempo by determining the period of a detection function [2]. It filters frames of audio into subbands that mimic how the human ear perceives sound, differentiates the subbands, sums the result, and autocorrelates the resulting function. The maximum autocorrelation value for a nonzero delay is found, and the tempo is calculated from the delay at that value.



Once the tempo is known, the application calculates the number of frames between beats (the “frame period”). It sums the subbands’ energy with the energy in subbands delayed by multiples of that period and compares this value to the energy in othe subband sets. If the energy is higher than 80% of the maximum energy in the other subband sets, a beat is declared.

Results and Future Work

Current RoboNova capabilities:

- Dances in synchrony to music
- Detects and responds to pitch
- Plays simple melodies on a keyboard

Future work:

- Increase the fluidity of the RoboNova’s gestures
- Transfer algorithms to Hubo

References

[1] Park, I.W., *et al*, “Mechanical Design of Humanoid Robot Platform KHR-3 (KAIST HUMANOID ROBOT-3: HUBO)”, *The Proceedings of the 5th IEEE/RAS International Conference on Humanoid Robots*, 2005, pp. 321-326.

[2] Jehan, T. “Creating Music by Listening.” PhD Thesis. Massachusettes Institute of Technology (MIT).

Acknowledgements

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